

APPENDIX A

DESIGN ANALYSIS

RECONNAISSANCE REPORT

for

HARBOR OF REFUGE

GRAND MARAIS, MICHIGAN

Prepared by

**U.S. ARMY CORPS OF ENGINEERS
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Reconnaissance Report
For
Harbor of Refuge
Grand Marais, Michigan

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1. General Information

1.1 Introduction: This preliminary design was performed in order to determine the most cost effective method for rehabilitating the harbor of refuge in Grand Marais, Michigan along the southern shoreline of Lake Superior. The harbor is experiencing problems with sediment accretion. In December 2000, the University of Michigan (U of M) Ocean Engineering Laboratory completed a report titled Grand Marais Harbor Rehabilitation Design Alternatives (Report OEL-2001) prepared for Michigan Sea Grant College Program. The U of M report refined prospective design alternatives from The U.S. Army Corps of Engineers (USACE) Section 111 study for Grand Marais 1980. At the request of Planning Branch, this report only considers those alternatives discussed in the U of M study. The alternatives are referred to as the Original Alignment Alternative, the 15-Degree Alternative and the 55-Degree Alternative. Information regarding existing conditions was obtained from past reports and a May 2002 site visit.

1.2 Background: Grand Marais Harbor is a natural deep water harbor on the southern shore of Lake Superior in Alger County, Michigan (see Plate 1 for location and vicinity maps). In 1903, Grand Marais Harbor became an official harbor of refuge under the River and Harbor Acts of June 14, 1880 and May 17, 1950 (Reference 1). The Harbor currently operates with the two original parallel jetties, but the original timber pile breakwater has completely deteriorated (see Plates 2 and 3 for existing plan and cross section). The breakwater is non-functional and fully submerged leaving the harbor vulnerable to storms and sediment accretion. Without Grand Marais Harbor, light-draft vessels will be forced to navigate a 71-mile stretch of Lake Superior's most dangerous waters without a place for refuge (Reference 2). By Congressional order the USACE has been requested to consider constructing a breakwater, which is cost effective and will maintain the Grand Marais Harbor as a harbor of refuge.

2. **Design Alternative** As previously mentioned, all design alternatives would involve the construction of a rubblemound structure offering varying amounts of usable harbor area. These rubblemound structures would consist of three layers of stone, each having a different gradation, arranged in such a way that wave energy is absorbed and smaller stone is not lost. Rubblemound structures typically have relatively lower construction costs as compared to other design alternatives. However, maintenance costs tend to be higher. Another disadvantage to rubblemound structures is they allow for less usable area in the harbor than other types of structures.

3. Design

3.1 General: Coastal design procedures developed by the USACE in the Shore Protection Manual (Reference 1) and engineering and design manual "Design of Breakwaters and Jetties" are being used for design of the harbor repairs.

3.2 Topographical and Geotechnical: All topographical and geotechnical data was acquired from previous studies. Prior to final design and soil borings in the vicinity of the new breakwater would be required.

3.3 Layout/Orientation: Three different alignments for the rubblemound breakwater design have been considered (see Plate 4). Each orientation originates the breakwater at the south end of the east jetty and ends approximately 100 feet from the ordinary low water mark. The reason for ending the breakwaters short of the low water mark rather than tying them into the shoreline is to prevent stagnation within the harbor.

3.3.1 Original Alignment Alternative: The first design option for the orientation of the breakwater would be in a line parallel to the original breakwater that is submerged. The structure would extend 7,000 feet east shadowing the original breakwater possibly using stone from the old structure. This alternative offers the most usable harbor area of the three alternatives considered.

3.3.2 15-Degree Alternative: At an angle 15° clockwise from the original breakwater the second design alternative would extend the structure approximately 4,800 feet to the south shore just west of the entrance to the east bay. The usable harbor area provided by this alternative is less than that of the Original Alignment Alternative but more than the 55-Degree Alternative.

3.3.3 55-Degree Alternative: The third orientation for the breakwater is at an angle of 55° clockwise from the original breakwater. This alignment results in a 2,500-foot breakwater extending to the south shore just east of a large drop in elevation in the bay from approximately 7 to 53 feet. This alternative offers the least usable harbor area of the three alternatives considered.

3.4 Structure Geometry: The geometry of the rubblemound structure varied slightly between the two proposed project sites due to the difference in wave heights.

3.4.1 Original Alignment: Based on a 20-year design wave height of 13.8 feet and a top of structure elevation of +7.0 above low water datum (LWD), the armor stone for the rubblemound placed along the original breakwater alignment would range in size from 6 to 12 tons with a majority of the stone being larger than 8 tons. The minimum layer thickness calculated for the armor stone is 9 feet and the crest would be 14 feet wide. The underlayer stone at this site would range between 1,100 and 2,100 pounds and would need to be a minimum of 4 feet thick. The core stone, or bedding stone, would consist of a 2-foot layer of stone ranging in size from 4 pounds to 100 pounds. A typical cross section of the rubblemound placed along the original breakwater alignment can be found on Plate 5.

3.4.2 15-Degree Alignment: Based on a 20-year design wave height of 10.7 feet and a top of structure elevation of +7.0 LWD, the armor stone for the rubblemound placed along the 15-degree breakwater alignment would range in size from 3 to 6 tons with a majority of the stone being larger than 7,500 pounds. The minimum layer thickness calculated for the armor stone is 7 feet and the crest would be 11 feet wide. The underlayer stone at this site would range between 500 and 1,000 pounds and would need to be a minimum of 3 feet thick. The core stone, or bedding stone, would consist of a 2-foot layer of stone ranging in size from 2 pounds to 50 pounds. A typical cross

section of the rubblemound placed along the 15-degree breakwater alignment can be found on Plate 6.

3.4.3 55-Degree Alignment: Based on a 20-year design wave height of 8.7 feet and a top of structure elevation of +7.0 LWD, the armor stone for the rubblemound placed along the 55-degree breakwater alignment would range in size from 3,000 to 6,000 pounds with a majority of the stone being larger than 4,000 pounds. The minimum layer thickness calculated for the armor stone is 6 feet and the crest would be 9 feet wide. The underlayer stone at this site would range between 250 and 600 pounds and would need to be a minimum of 2.5 feet thick. The core stone, or bedding stone, would consist of a 2-foot layer of stone ranging in size from 1 pound to 20 pounds. A typical cross section of the rubblemound placed along the 55-degree breakwater alignment can be found on Plate 7.

4. Construction Considerations A May 2002 site visit found no land access for construction of any of the alternatives. Therefore, it was assumed that construction would be marine based. This type of construction would require some dredging of the harbor to accommodate the draft required by the construction vessels. It was assumed that a 50-foot wide channel dredged to an elevation of -10.0 would be required.

Other relevant assumptions include no necessary dredging of the harbor and no removal of the existing pile dike structure.

5. Cost Estimate A working cost estimate was developed for each of the alternatives previously discussed. Quantities used for preparation of the estimates were based on the preliminary design presented in this report and a cost summary can be found in Appendix B. Costs for the different alternatives are as follows:

<u>Alternative</u>	<u>Cost</u>
Original Alignment	\$15,840,000
15-degree Alignment	\$ 8,883,000
55-degree Alignment	\$ 3,670,000

6. Conclusions While the 55-degree alternative has the lowest construction costs of the three alternatives, it provides for a smaller harbor than the original alignment or the 15-degree alignment. Therefore, the needs of the harbor would need to be better defined before a recommendation could be made as to which alternative best suits the harbor.

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References

1. University of Michigan, Ocean Engineering Laboratory; Grand Marais Harbor Rehabilitation Design Alternatives; December 2000.
2. U.S. Army Corps of Engineers; Grand Marais Harbor, Michigan Reconnaissance Report on Reducing Future Maintenance; November 1978.
3. U.S. Army Corps of Engineers; Coastal Engineering Research Center; Shore Protection Manual; Second Printing 1984.
4. U.S. Army Corps of Engineers; Design of Breakwaters and Jetties, EM 1110-2-2904; 08 August 1986.